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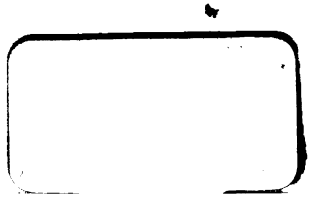
MANUALS OF THE SCIENCE AND ART OF TEACHING.

ADVANCED SERIES

No. 4

HOW TO TEACH ANIMAL PHYSIOLOGY.

MANCHESTER.



Manuals of the Science and Art of Education

ADVANCED SERIES—No. IV.

HOW TO TEACH ANIMAL PHYSIOLOGY

LONDON
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The wide circulation of the National Society's Manuals on the 'Science and Art of Teaching,' has induced the Literature Committee to undertake another series of Manuals on more advanced subjects, which they trust will be useful not only to Teachers in Elementary Schools and Students in Training, for whom they are primarily intended, but also to Teachers in Secondary and Higher Grade Schools.

The Manuals of the present series—like those which have preceded it—have been written by men of distinguished reputation in their various subjects, and who have had large experience as teachers and examiners. They include all the subjects in Schedule 4 of the Education Code with the exception of Mathematics, which is fully treated in the 'Pupil Teachers' Course of Mathematics,' published by the Society. The Manual on Teaching Languages has been planned to comprehend the teaching of German and French as well as Latin. In addition to the subjects under Schedule 4, the present series includes a Manual on the Training of Pupil Teachers, by a very successful Lecturer on Method in one of the larger Training Colleges.

In order to obtain greater clearness and precision, each subject has been treated independently, and is complete in itself.

ANIMAL PHYSIOLOGY.

CHAPTER I.

CLAIM OF HUMAN PHYSIOLOGY TO ATTENTION.

1. **Past neglect and present prejudice.**—No one science is of more value to us as human beings, perhaps none is of so great value, as Physiology, when we consider of what that complicated sum-total which we call 'human happiness' consists. Yet no science has received less attention in the past, and against none is there so great prejudice in the present. These two facts, taken together, however, give little or no cause for regret. The past universal neglect sprang of ignorance of the subject, strengthened and maintained by that preference of the ornamental before the useful, so characteristic of mankind; whilst the present contention marks the second stage in the growth of all human knowledge, that of enquiry. We may, therefore, logically look forward in the future to a period when unanimity will once more be established, but the unanimity of regard, not of disregard.

The existing prejudice against Physiology lies, not in its truths, but in the way and spirit in which those truths have been propounded: in other words, the origin of the prejudice must be sought, not in the science, but in certain exponents of that science. The disappearance of this pre-

judice, therefore, is only a question of time, and he will do good service who shortens that period.

2. Its rational claim.—Nothing would seem more rational than that human beings should be prepared for 'the battle of life' by being carefully taught all that is certainly known of the nature and use of the weapons with which that fight must be fought. Indeed, if the question were to be settled by reason, and reason only, there could be no doubt of the decision. 'The proper study of mankind is man.'

Who would hope to become a mechanic without serving an apprenticeship, during which he would acquire such special knowledge of the materials with which he worked, and of their properties, as would enable him to turn them to profitable use? Yet human beings are supposed to be fitted for life by an education that finds in it no place for Physiology! Our youths are expected to become acquainted with, at least, the outlines of the geography of their native land, and some knowledge too of their race is expected:—room can be, and is, found for geography and history, but none for Animal Physiology! To know anything of the landmarks of one's own system, or how the simplest and most necessary function of the body is discharged, or the history of any secretion, however frequent and important its use, is deemed quite unnecessary by the great mass of both parents and teachers.

An engineer must know something of a steam-engine, and of the physical laws in virtue of which it does its work, yet men and women are supposed to be able to educate children without knowing anything of the structure of those children, of the laws of human life, of the order in which human powers are developed, or of the nature and uses of those powers.

Now, although *habit* and *fashion* are stubborn opponents, yet this state of things brings such abundant disastrous consequences, and is so irrational, that it cannot continue. Ere

long it must certainly be demanded of all who claim the title 'TEACHER,' that they shall know something of the human subject whose development they are to aid, and whose future welfare, both in this world and the next, depends to so large an extent upon the treatment received at their hands.

3. Consequences of neglect of Physiology.—Let us glance at some of these disastrous results. We shall find them everywhere; in our homes and in our schools; affecting teachers and parents, as well as children.

We value wealth; we value power; we act as though we did not value life and health. We take great pains to secure the former, the latter are disregarded. Yet what would one give for health when gone, and how little, given at the right time, would save it! Often the most trifling physiological knowledge would have saved health irreparably ruined, and have handed on to children unimpaired constitutions.

Our children are not cared for nearly so well as many other of our worldly possessions. This is mainly because we make no more effort to understand child-life than we do to understand our own.

(a) *Intellectual.*—A little thought will show that the laws of life must underlie all bodily and mental processes, and a knowledge of them must therefore be of the highest importance. In spite of this the school-life of a child has been almost wholly artificial, being hedged about in all directions by fences and notice-boards giving warning that 'trespassers will be prosecuted.' These barriers and prohibitions were frequently placed directly across natural paths, for example, across that *childish inquisitiveness and restless activity*, which by those 'gateways of the mind,' the senses, open so soon communication with the external world.

During the last few years many of these fences have been rooted up and notice-boards removed, and so school

life has become much more natural and, therefore, more healthy and moral than it was; but before all these artificial restraints can disappear the laws of physiology and of psychology must be more perfectly known and acknowledged than at present, both by parents and teachers. School life must be an unbroken and unchecked continuation of those first and wonderfully successful five or six years of child life that give a language and no mean acquaintance with natural objects and natural phenomena.

Ignorance of the laws of life leads us to thwart much natural child effort after knowledge, often at the cost of a large expenditure of effort on our part. So there is a double loss of energy, a loss both on the side of the child and on that of parent or teacher.

(b) *Physical.*—And not only in this direction is evil being wrought, but physical ill-consequences are wofully abundant. The seeds of future life-long weakness or disease have frequently been sown in a dirty, ill-ventilated, imperfectly warmed, badly lighted, inconveniently seated, and wholly unadorned schoolroom; or have originated in studies too prolonged, too little broken or relieved, or undertaken too soon after a heavy meal, at a wrong age, or under wrong conditions; or have proceeded from improper methods of work, or still more improper modes of punishment. Herbert Spencer [1] says :—

'If any one doubts the importance of an acquaintance with the principles of physiology as a means to complete living, let him look around and see how many men and women he can find in middle or later life who are thoroughly well. Only occasionally do we meet with an example of vigorous health continued to old age; hourly do we meet with examples of acute dis-

[1] *Education: Intellectual, Moral, and Physical.* By Herbert Spencer.

order, chronic ailment, general debility, premature decrepitude. Scarcely is there one to whom you put the question who has not in the course of his life brought upon himself illnesses which a little information would have saved him from. Here is a case of heart disease consequent on a rheumatic fever that followed reckless exposure. There is a case of eyes spoiled for life by over study. Yesterday the account was of one whose long-enduring lameness was brought on by continuing, spite of the pain, to use a knee after it had been slightly injured. And to-day we are told of another who has had to lie by for years because he did not know that the palpitation he suffered under resulted from over-taxed brain. Now we hear of an irremediable injury which followed some silly feat of strength; and, again, of a constitution that has never recovered from the effects of excessive work needlessly undertaken. While on every side we see the perpetual minor ailments which accompany feebleness.'

(c) *Moral.*—Moral ill-consequences are equally numerous in any system of education that does, or attempts, violence to the laws of life. Those artificial fences could not stop all; some, and those of the best, would be irresistibly compelled to get *over* or *under* them, and with what damage to their morals is easily conceived. In fact, the moral results, under such circumstances, must necessarily parallel the physical.

The extent of all these evils, physical, intellectual, and moral, can scarcely be exaggerated. Physiology supplies the remedy so urgently needed.

4. Partial acknowledgment of claim.—Happily schools and school life have, of late years, lost much of their

artificial character. Thus commodious, neat, and cheerful schoolrooms have been built in accessible places; they are well ventilated, well warmed, and well lighted; convenient seats and desks have been provided, even blinds may be seen to schoolroom windows, and pictures, casts, and flowers on their walls and shelves; playgrounds are attached; a time-table, that secures frequent changes, a rational arrangement, and suitable breaks in the work, has to be approved by Her Majesty's Inspectors; singing and drill have found a place in school work; and, lastly, teachers are placed at the head of each school, who have not made teaching a 'dernier ressort,' but a settled purpose of life from the first, and have in many cases learned something of Human Physiology.

Still, education can never be what it ought to be, until teachers themselves know and fully appreciate those biological laws that alone can provide a solid foundation for any true method of education. The art of teaching must be founded directly on the science of life. Therefore all teachers should have, at least, a knowledge of the elements of Animal Physiology, and in training colleges the school management lectures should include a short series on the leading principles of psychology.

5. Practical value.—Besides the improved national health and happiness that must come from a wide-spread though elementary knowledge of the general laws of health, the value of cleanliness, and the evils of dirt and vice, the necessity of pure water and fresh air, of bodily and mental exercise, and the advantages of a temperance which is exercised in all directions—besides all this a knowledge of physiology is also of direct practical value in many of the accidents of life. How many persons have bled to death or been drowned before medical assistance could be obtained, whose lives could easily have been saved by one who had only a very elementary knowledge of the circulation of the blood, or of the true nature of respiration.

6. Relation to general education.—Education, whatever form it takes, has for its purpose the preparation of its subjects for complete living; and entire success in all directions cannot be reasonably expected from any scheme that does not include Animal Physiology. Again to quote Spencer:[1] 'How to live is the essential question for us. Not how to live in the material sense only, but in the widest sense. The general problem which comprehends every special problem is—the right ruling of conduct in all directions under all circumstances. In what way to treat the body; in what way to treat the mind; in what way to manage our affairs; in what way to bring up a family; in what way to behave as a citizen; in what way to utilise those sources of happiness which nature supplies—how to use our faculties to the greatest advantage of ourselves and others—how to live completely? And this, being the great thing needful for us to learn, is, by consequence, the great thing which education has to teach. To prepare us for complete living is the function which education has to discharge, and the only rational mode of judging of an educational course is to judge in what degree it discharges such function.'

(a) *Of Everybody.*—By no other study than that of the sciences, and by no one science so well as by physiology (including psychology), is this function fully discharged. In every aspect of human life it exercises great influence, directly or indirectly, from the pursuit of the earliest art, agriculture, [to the 'Fine Arts,' sculpture and painting: so, in every stage in the progress of any one human life, it equally has a most important bearing; on the child, the youth, the young man, the father, the citizen.

(b) *Of Teachers especially.*—It has been said that a 'true philosopher' alone can be a *good* teacher; and there is so much truth in the saying, that the office of a teacher,

[1] *Education: Intellectual, Moral, and Physical.* By Herbert Spencer.

if rightly discharged, should be esteemed as most honourable by society, and by himself as of the highest importance. When the sciences of physiology and psychology shall have become perfect, then we may look for a perfect scheme of education, and the required philosopher may become a possibility. Till then, it is only by making our art of teaching accord with the ascertained truths of these sciences that we can reasonably hope to achieve great success; and any success we do achieve will be in exact proportion to the accord of our methods with those truths.

It must ever be borne in mind that education is a drawing out of natural powers, and that the real work of the teacher is to help natural development.

Now there is much solid land reclaimed from the swamps of ignorance in physiology, and on that land every teacher should be able firmly to plant his foot; thence he can take care that none of his methods run counter to the laws of child life; thence he can secure the co-operation of those natural laws with his own efforts. Thus he will ever have in view, when framing his plans, as when carrying them out, the principles that decide and guide his work, and will consequently feel that earnestness, certainty, and interest in his work that comes in no other way, and that, since it awakens like interest and earnestness in his children, leads more than anything else to a successful issue. He will thus compel the children to like their work. Show us a school where truants are regular and natural products, and we will show you one where the truths and laws of physiology are daily and hourly outraged.

(c) *Of their Pupils.*—The advantages of some knowledge of physiology are tolerably evenly distributed amongst teachers and taught. We have looked at it from the teacher's side; let us look at it from the child's.

Physics, chemistry, and physiology have been called the 'useful sciences,' and, from a purely utilitarian point of view, physiology forms a fitting climax to the three: it is the natural goal towards which all other sciences tend.

And here we see another reason for its late development and for its tardy appreciation. Like geology (specially palæontology) it is a descendant of the earlier sciences, and its existence has only become possible by the more or less perfect maturity of those earlier sciences.

No acquired knowledge has greater, if so great, intrinsic worth to a human being, as the undisputed facts and laws of physiology. They will be fraught with benefits to every possessor from the school to the grave. The pursuit of that knowledge is scarcely less valuable as a means of mental discipline.

7. Physiology as an educational instrument.—Physiology, when properly taught, is a most potent educational instrument, and gives, moreover, reality to knowledge by frequently bringing it into direct contact with absolute fact.

(a) *Physically.*—Physically it sharpens the senses, especially the more useful ones of sight and touch; establishes that complete unity of purpose between eye and hand, so necessary in all our more delicate and important undertakings; and in the proper gradation of the subjects of study presented to the child, engenders a thoroughly healthy physical development of the brain and entire nervous system, analogous to that of the motor organs which comes from judicious bodily exercise.

No study will better help to develope an intelligent memory, specially if the *thing* is known before the *name*, and the derivation or meaning of the word always clearly given with its first use. Physiology may lay a special claim to memory on physical grounds, since there is evidence that loss of memory is a direct result of a physical change in the condition of brain matter, producing as effective a mental blank as would loss of sight, or of any other sense that links the brain to the outer world. Memory, therefore, being based on a nervous property, is sustained by nutrition and stunted by inaction.

(b) *Intellectually.*—Intellectually it makes voluntary attention easy by utilising from the first, and to the full, that universal interest children take in living things, and so that habit of attention is acquired, which, through well-defined sensation and consequent clear perception, makes classification and generalisation or abstraction possible, and ultimately, in the higher stages, finds scope for imagination, conception, and inference or judgment. If practical work is not abused, the study of Physiology may even begin to develope those higher powers at a comparatively early stage.

(c) *Morally.*—Morally, physiology will, if taught in a right spirit and by right methods, do much to lessen that childish cruelty to animals, alas! so often conspicuous, and may permanently deepen the humane side of our natures.

Since it is constantly protesting against the acceptance of any fact without rigid enquiry and searching test, *perseverance* and *honesty* will be fostered at every step, and a consciousness of power will be awakened that will lay a good foundation for manly independence and self-helpfulness.

8. Summary of Grounds of Claim.—These, then, are the grounds on which we claim for physiology much more general and particular attention than it at present receives.

1. Life is God's most precious gift to each of us, and perfect living therefore our highest duty, and without a knowledge of physiology perfect living is impossible.
2. In education, when physiology rules our conduct, we shall secure the maximum effective result of the labour of both child and teacher.
3. Physiology has already by legislation rendered schools pleasant places, and is, although too slowly, making school-work equally attractive, and will, when its principles shall fully guide the legislation of the

Educational Department and the methods of teachers, altogether change the character of school-work for the better, as regards teacher and taught.

4. The truths of physiology possess an intrinsic value equalled by no other science, for each of its acknowledged compeers, chemistry and physics, has a more or less restricted application, whilst that of physiology is coincident with humanity.
5. As an educational instrument it compares not unfavourably with mathematics and languages in its general result, and claims special merit for producing physical as well as intellectual and moral consequences, which moreover interact upon each other.
6. Ultimately it will put home and school into perfect harmony with each other, and school years will form some of the brightest links in the golden chain of life. When physiology and psychology guide all educational methods, *home* will lead up to the duties of *school*, and school will fit for the duties of home.

CHAPTER II.

WHAT TO TEACH.

1. **Limits of sciences artificial.**—In teaching physiology it cannot be forgotten that the division of human knowledge into sciences is wholly artificial, and has for its sole *raison d'être* human convenience. There are no definite natural boundaries between science and science, but the one passes insensibly into, or rather overlaps, the other, so that there is a considerable portion of territory common, and only the very centre of each realm is peculiarly its own. Thus, though each science has its own laws, yet those laws have a much less restricted application than that indicated by the science itself. Whenever the necessary conditions are found in physiology, the laws of chemistry, &c., exercise full sway, and under all circumstances are factors in the results obtained.

Hence it is quite impossible to approach the study of animal physiology till a certain amount of progress has been made in those sciences from which its roots draw nourishment, and equally impossible to pursue it deeply without a knowledge of another group of sciences into which its branches extend. Thus physiology joins hands on the one side with physics, chemistry, and anatomy, and on the other with geology, physical geography, and astronomy.

2. **Requirements in teacher.**—It is not to be supposed that a child must study physics and chemistry before he can begin the study of physiology, but his teacher should

make himself sufficiently master of these subjects to be able to put clearly before his class the properties of the materials dealt with in each particular case, the laws to which they conform, and their chemical affinities.

It will be readily seen that a knowledge of anatomy is indispensable to both teacher and pupil.

A preliminary course of physics and chemistry is therefore desirable for the teacher, but is by no means necessary for the child.

Each lesson should contain so much anatomy as is required, and such simple experiments in chemistry and physics as are essential to an intelligent understanding of the physiological function under consideration.

Teachers, therefore, should be acquainted with the forms and properties of matter, the physical forces and their mutual convertibility, the so-called elements, specially oxygen, hydrogen, nitrogen, and carbon; such ordinary compounds as air, water, carbonic acid, common and lime salts; the difference between mechanical and chemical, stable and unstable compounds; and with the general anatomy, not only of man, but (at the least) of other *mammalia* also.

3. Only teach what is certainly known.—In animal physiology, at present, there is necessarily much that is uncertain, debatable, or purely theoretical. A teacher will show his tact in only so far noticing these portions as to direct attention to the growing points of the science, and so suggest paths to be subsequently trod.

Thus a first separation will be made between the well-established and essential portions of the science, and those doubtful or unimportant. Physiological facts and fundamental principles will be clearly distinguished from mere opinion. Lastly, a careful selection must be made even from those facts themselves. As Foster says,[1] 'To tumble out all the treasures from the physiological treasury is simply to bewilder, not to teach.'

[1] *A Text-Book of Physiology.* By M. Foster, M.A., M.D., F.R.S.

Some physiological facts are at present wholly inexplicable; these should be plainly and candidly stated. How nerve energy brings about a state of consciousness? How cerebral substance evolves intellect? How nerve stimulation becomes feeling and reason? The essential physical difference between pleasure and pain? How the mind comes to attention?

4. Three Courses in Physiology.—There should be three courses in animal physiology, each suited to the age and mental development of the pupil. Each course possesses peculiar educational merits. Each should be perfectly complete in itself, so that, should the first course fail to be followed by the second, or that by the third, the time and effort spent would not be lost, for the knowledge acquired would be serviceable, since the outline would be perfect, although details would be more or less lacking; moreover, the discipline would be valuable.

(a) First Course.

General Remarks.—The first course should have as its primary object the exercise and consequent strengthening of the senses, especially of sight and touch. During this period, the fingers should become deft, and the eye keenly and accurately observant.

It should take the place of the ordinary 'object lesson,' and would secure all thereby gained, *plus* those advantages that come from continuous and progressive study.

It should end in the acquisition of a considerable store of facts by such close and careful observation as will, by practical use, have become a confirmed habit.

Only the more evident physiological phenomena should be dealt with, and these only in outline; such phenomena, that is, as the respiratory movements, heart-beat and pulse, change in size of pupil of eye, and ordinary voluntary muscular movements.

COURSE:

1. *Body generally.*—This first course should deal with the body as a whole, should be analytical and almost purely anatomical. It will begin with the general build of the body, its symmetry and bilateral character.
2. *External Organs.*—Starting with the self-evident pairs of organs, it will lead up to the double structure of such median organs as the nose and mouth. A careful study of these external organs will be made, first individually, and next reverting to their bilateral character.
3. *Internal Organs.*—The position, size, shape, general character, and movements (if any) of the external organs having been observed and recorded, the internal organs should next receive attention, again, absolutely first, and afterwards as possessing a bilateral structure similar to that of the external organs.

   This should be shown first in such cases as the kidneys, lungs, brain, and next in such as spinal cord, heart, and tongue. Good models of these should be placed in the children's hands. Models will generally be preferable in this preliminary course to actual organs.
4. *Skeleton.*—Bones might, however, be seen and handled. Their shape, size, relative positions, and means of union into the complete skeleton should be known.
5. *Function.*—This course should terminate with a separate brief consideration of organs as related to their functions. By using the knowledge of the body now acquired, the general relation between organ and function may be pointed out, and so the relation of anatomy to physiology be understood. This course thus ends with a distinct

knowledge of the real province of physiology, which the children may now define for themselves.

(b) SECOND COURSE :

General Remarks.—The second course should aim not only at the acquisition of scientific facts, and at the development of the powers of observation, but also at the strengthening of the reasoning powers. Reasoning, however, must not displace observation, for experiment and practical work will still form the basis of all study. Anatomy will now become distinctly subordinate, and physiology prominent.

The *function* should be the start-point of each enquiry, and the fitness of the organ for the discharge of its function should be persistently sought. Let results be observed, causes looked for, and purposes discovered. Let the prominent questions all through this course be 'HOW IS WORK DONE?' and 'WHY IS WORK DONE?'

Thus with the organs will be associated their proper functions; the principle of 'division of labour' will be recognised in the human body; and the suitability of each organ in position, form, and substance, for the work it has to do, will be seen by a study of the broad structure of such organ.

The work of each organ should be considered as a whole, and no attempt be yet made to track it to its primary source in cell-action.

The models might here, at least occasionally, give place to actual organs from ox, sheep, pig, or rabbit. Children at this age will not shrink from handling the parts, and in so doing will learn how much the real thing is superior to any description, or picture, or even model. A model may give size, form, colour, and general appearance truthfully, and is superior to a picture, since it may be viewed from different positions, and is, indeed, equal to a series of pictures in *every* position; but it cannot give texture, and is useless for dissection. A model may satisfy the sense of sight, but cannot satisfy touch, taste, &c.

COURSE.—This course, starting with the more obvious movements of the body, will track them backwards to their source, and forwards to their ultimate results. Thus, from organs the pupil will pass on to systems, and see how organ is combined with organ, and function co-ordinated to function in the production of one common result.

1. *Circulatory System.*—The heart-beat and pulse motion already noticed will lead back to the circulatory system, then forward to its *modus operandi*, and the purposes, thereby served, of cleansing, nourishing, warming.
2. *Respiratory System.*—The respiratory phenomena as naturally suggest enquiry into their cause and purpose, whilst the *cleansing* work of the blood points to a connection between the circulatory and respiratory systems, the *nourishing* work between the circulatory and alimentary, and the *warming* work between the circulatory and nervous. The respiratory phenomena, system, and function should therefore come next.
3. *Excretory and Secretory Organs, with Alimentary System.*—The pupil, through the consideration of excretions and excretory organs, and of secretions and secretory organs, should pass to the examination of the means by which these losses are made good in the functions of alimentation and nutrition.
4. *Motor Mechanisms.*—The means by which all these and other simple and complicated movements of the body, or its parts, are produced, should next receive attention.
5. *Nervous System.*—Finally, the general nervous system, by which all is regulated, directed, and controlled, should be studied.

This course, therefore, commencing with the blood and its functions, should end with the brain

and its general function, leaving the special and detailed consideration of the senses for the next course.

(c) THIRD COURSE.—This course should aim at securing a tolerably full knowledge of the structure of the organs of the body, of the way and exact place in which they perform their respective functions, and of the principles in virtue of which they are enabled to do their work.

The first course has given accurate knowledge of the body as a whole and of its organs; the second course of the functions discharged by those organs; and this third course should aim at discovering exactly *where* and *how* each organ does its work, and at writing a *history* of organ and tissue.

General Sketch.—This course should, therefore, begin with a minute study of the various tissues, and of their characteristic properties; should then consider how these fundamental tissues are combined and arranged as mechanisms; and, finally, how they are welded into an organic whole. It will not be advisable to examine the structure and function of *all* the tissues first, then of *all* the organs, and last of *all* the systems; but rather to take first the more important and common tissues, and notice the others as the organs in which they are prominent come under notice. The organs and systems should be similarly treated.

Huxley's Elementary Text-book[1] exactly covers the ground, and is a model for precision and cautious statement, for brevity, lucidity, and point, and for its logical arrangement and developmental character.

If space would permit, no purpose would be served by specifying the exact work in this course. Briefly, therefore, let a searching enquiry be conducted first into the blood, then into the excreting and secreting

[1] *Lessons in Elementary Physiology.* By Thomas H. Huxley, LL.D., F.R.S.

tissues, and next into muscle, bone, &c.; but let the great attack be made on the 'keep' of the physiological castle, the nervous systems, sensations and the sensory organs. To this attack all preceding enquiry has been preparatory, and from a teacher's point of view, before this, all other enquiry sinks into littleness. Finally, such special phenomena as coagulation of the blood, lymph, &c., loss of pulse in blood capillaries, and formation of glycogen in the liver, may now be confidently attacked; as, also, the action of the larynx in the production of voice, and of nerves on secretory and excretory organs; and, lastly, much educational advantage will be secured by a critical examination of many so-called simple sensations and delusions of the senses.

For students in training colleges this course should clear the way to an intelligent study of the leading principles of psychology in their school management work of the second year.

CHAPTER III.

WHEN TO TEACH PHYSIOLOGY.

All through School Life.—The necessity for finding means, consistent with the necessary discipline of a school, to cultivate the observing powers of young children has long been felt, and attempts have been made in that direction with varying success. The natural inquisitiveness of children and their instinctive desire to handle the things they see has long suggested to thoughtful teachers that therein existed, ready-made, a powerful means of acquiring knowledge.

Lessons on common things, natural history lessons, and object lessons generally; ball-frames, form and colour boxes, are all attempts to turn this curiosity and tendency to confirm the evidence of one sense by another into useful channels, and have all been attended with more or less success.

In the majority of cases, however, this effort stops abruptly at the end of the infant-school course, being wholly discontinued in the boys' or girls' school. This is a mistake. It should not disappear suddenly, but, ceasing to be the prominent feature in the teaching, should gradually sink into the back-ground as the mental development of the child progresses, and should never wholly disappear even in the first class; but mere external examination should advance to internal, and then to simple test and experiment.

The study of physiology should, therefore, begin in the infant-school and continue through the entire school life.

FIRST COURSE.—The first course should begin in the infant school with the examination of the external organs, and be continued until the child has reached the fourth standard. It is a great mistake to *begin* this course when a child is preparing itself for the fourth standard; it should culminate at that standard. Yet this mistake is commonly made, and probably will continue unless physiology be made part of the ordinary school-work. A child from the beginning of its school career should be acquiring, and pleasantly too, much anatomical knowledge that it will subsequently need, and will at the same time cultivate its senses, develope for itself an intelligent memory, and from the continuity of its object lessons learn the value of unity of purpose.

The lessons should be short, and not too frequent, and would certainly be valued more if made contingent on other work being well done. They will thus come to be regarded as rewards, and their natural attractiveness will be so increased that the impressions made will be very lasting. The lessons might vary in length from thirty to forty minutes and be given once a week only, often with manifest advantage at the end of the week. We have known an irregular Friday afternoon attendance completely cured in this simple, useful, and pleasant way. This course should terminate at the age of ten or eleven.

SECOND COURSE.—The second course should occupy the latter part of ordinary school life, from the age of ten or eleven to that of thirteen or fourteen, when to observation and memory will be added some power of reasoning.

It will be well within the reach of a child of ordinary intelligence, and, if the first course has done its duty, will be approached with eagerness.

At this age we may begin to present real objects for examination, and such skill in drawing ought to have been acquired as will enable the pupil to sketch the objects seen and the sections made; indeed, the note-books should mainly contain sketches, the only writing being the names

of the objects and their parts, and records of changes in colour, solidity, &c.

There should be two lessons per week, which might be conveniently given on Wednesday and Friday afternoons. The first would vary from 45 to 60 minutes in length; the second would rarely or never exceed 45 minutes. The two lessons should cover the same ground, the first partaking of the character of the ordinary object lesson, and the second forming a preparation for private study. The latter should consist of reading from the text-book, and comparing and testing the account therein with and by the object itself. The second lesson, if properly used, would lead to future personal study when school-days are ended.

THIRD COURSE.—The third course is suitable for pupil teachers, students in ordinary science classes and in training colleges, and if ever night schools should carry on and not repeat the work of day schools there too it may find a place.

There should be not less than two lessons or lectures per week, and each should be of, at least, one hour's duration.

This course may begin at about fifteen years of age, but not much earlier, as demands will be made for the frequent exercise of the higher mental faculties, some of which are of late development.

This course ended, the pupil will approach manhood in some degree fitted both to appreciate and discharge the responsibilities incident to that state.

CHAPTER IV.

HOW TO TEACH PHYSIOLOGY.

1. **Objects.**—To teach anything well, one must see clearly at the outset all that it is possible or desirable to secure in the study of that subject.

The following objects may be secured in the study of animal physiology, and to that end should be continuously present in the teacher's mind:—Keen and precise observing powers; sound, solid knowledge, and, therefore, clear scientific ideas; all those intellectual advantages that come of continuous and progressive study, the habits of comparing, classifying, and assigning the due relative values to facts; the power of reasoning on, and drawing inferences from, facts; that of detecting a common principle in dissimilar phenomena, and so of enunciating natural laws; and a wise discrimination in the choice of language for definition.

2. **Means.**—Certain means are available to this end, viz., LESSONS, PRACTICAL WORK, and EXAMINATIONS.

In the lesson, the brunt of the labour falls on the teacher; in the examination, on the pupil; whilst in the practice, it is about equally shared by each.

(a) THE LESSON OR LECTURE.—In the lesson the teacher is personally responsible to a very large degree for results.

In all lessons, *examination* of structure should precede that of physiological function, although it is sometimes advisable to *notice* the act and even the function first.

The lesson should consist of an inspection of the object

or act; any physical or chemical experiments needed to understand the phenomena; verbal description or lesson proper, accompanied by illustrations, and concluding with summary and definition. Questions should, of course, be scattered through the lesson at discretion, and the summary should, as far as possible, be the work of the pupils.

Spirit of Teacher.—The ultimate success of the work depends much on the spirit in which the lessons are given. That enthusiasm in a teacher begets enthusiasm in his class needs no enforcing, but that a teacher should be careful not to teach in a destructive spirit does. What the teacher is in opinion, the class is to a very large extent, but not in knowledge, experience, or judgment. The teacher's legitimate work is constructive, and to turn aside for the purpose of aiming, what is thought, a crushing blow at some other subject (and that not a scientific one) is ungenerous, inopportune, and unfair. A witticism or sarcasm may produce results wholly incommensurate, and may secure an end that could not be reached by fair and honest argument. The class or lecture room is not the place for contention; all debatable points should be studiously avoided, and opinions on side issues never obtruded.

A modest, honest, enquiring spirit, which, in the search for truth, is prepared to meet difficulties that may be insurmountable, should be that of every teacher. No teacher of physiology must be ashamed to acknowledge, 'I DON'T KNOW.'

Technical Terms.—With children, and even elder pupils, save those who have some knowledge of Latin and Greek, the technical terms present one of the greatest difficulties. There is often more alarm felt by the pupil than there need be. All this alarm and much of this difficulty will vanish, if, invariably, the teacher carefully pronounces and spells every new word, makes his pupils write it, shows its derivation (except in the first course), and then gives its precise meaning.

The teacher and examiner should remember that apparently gross errors are frequently only slips of memory as regards these technical and, as yet, somewhat unfamiliar terms.

Value of Drawing.—By teacher and pupil alike, in physiology, drawing can hardly be valued too much.

The teacher should have diagrams ready prepared, and should also freely use the black board. The prepared drawings will be all the better if made by the teacher himself. Not only will every stroke and shade be significant to him, but the pupils will feel they can do what their teacher has done.

Physiological sheets, such as Johnston's [1] or Marshall's,[2] are better, as a rule, for reference in preparatory work, or on writing reports, than for class purposes.

In sketching on the black board, it is a great advantage to have coloured chalks, and always to use the same colours to represent the same parts, as white for ordinary outlines, red for arteries, blue for veins, yellow for nerves, &c.

The pupil should study the illustrations in his text-book, since they must often take the place of model or object; he should copy the diagrams employed by the teacher in his lesson; and no report should ever be accepted that is not illustrated by sketches.

(b) PRACTICAL WORK.—Besides what is done by the teacher in his lesson, a special time should be appointed for practical work by the pupil, under supervision.

Conduct of Experiments.—The teacher should remember that much harm may be done to morals by an inconsiderate mode of conducting experiments. Animals, even when dead, may be so handled as to produce either hardness and

[1] *Johnston's Illustrations of Natural Philosophy.* Sheet No. 6, Physiology.

[2] Physiological Diagrams, produced under the direction of John Marshall, F.R.S., F.R.C.S., Professor of Surgery, University College, London, for the Department of Science and Art.

cruelty, or to raise such feelings of repugnance or disgust, that what would be a powerful friend is transformed into a foe. Consideration and feeling should be conspicuous in the conductor of any physiological experiment that deals with sometime living tissue.

In teaching physiology, there is not the slightest need for vivisection, which would, indeed, be wholly out of place, since it would answer no purpose that might not be served by other means. In original research it is undoubtedly a necessity, but class-work and original research are widely different.

Necessity of Practical Work.—The great importance of practical work, to a large extent through the persistent efforts of Huxley and Foster, is now pretty generally felt.

The former says ;[1]—

'It will be well for those who attempt to study elementary physiology, to bear in mind the important truth, that the knowledge of science which is attainable by mere reading, though infinitely better than ignorance, is knowledge of a very different kind from that which arises from direct contact with fact; and that the worth of the pursuit of science as an intellectual discipline is almost lost by those who seek it only in books.'

The latter says :[2]—

'I have supposed the reader to be willing to handle and examine such things as a dead rabbit and a sheep's heart, and written accordingly. I have done this purposely, from an increasing conviction that actual observation of structures is as necessary

[1] *Lessons in Elementary Physiology.* By Thomas H. Huxley. Preface to 2nd Edition.

[2] *Physiology.* By M. Foster, M.A., &c. Preface.

for the sound learning of even elementary physiology, as are actual experiments for chemistry.

Caution in Use of Practical Work.—Care must, however, be taken not to over-emphasize the value of experimental work.

Practical work may be almost wholly mechanical, and then it is almost useless.

As book-work without practical work is bad, so is practical work without book-work, or its equivalent—teaching. Either, alone or disproportionate, is imperfect and, therefore, comparatively bad. A judicious adjustment, in time and quantity, of the one to the other is the work of the teacher.

The pupil must not become a mere collector of facts or specimens. Collection without classification and generalisation is of little use. Work of the mind must succeed and complete that of the senses. As no one can build without materials, so one may have materials and yet be unable to build.

Foster says :— [1]

'Practical work is only of value in so far as it *suggests* or *corrects* ideas. The student who has mounted an exquisitely thin and beautifully stained section, is only just so much the worse for his pains (as far as physiology is concerned) if he does not *understand* what the section means.' (The italics are ours.)

The eye is an instrument of the mind, and what the eye sees, therefore, depends on the state of the mind. The mind sees, not the eye; hence, as a general rule, what the eye sees is what is looked for. Book-work, therefore, has its legitimate and necessary work in so preparing the mind that it may tell the eye what to seek.

Again, there is no need to see or do everything; indeed,

[1] *A Course of Elementary Practical Physiology.* By M. Foster, M.D., &c., assisted by J. N. Langley, B.A.

as a matter of intellectual discipline, it is unadvisable; in much research it is impossible so to do, and, therefore, education should prepare a child to deal with such cases. Conception and imagination must have exercise if their growth is to be healthy and vigorous. The better the educational work has been done, the less will the pupil feel the necessity of actually seeing or doing everything.

Record Experiments.—Dissections and other practical work should be first done by the teacher, and then by the pupils, either individually or in groups, according to circumstances.

Although the pupil should work under direct supervision, he should be allowed to do so as independently as possible.

Teachers will do well to insist on having everything sketched and described on the spot, while the object is at hand to be appealed to in any case of doubt or indecision. Remember that any record loses value as the interval widens between the making of the observation and its record; and that, therefore, generally, those accounts will be truest and fullest that are made at the actual time of observation.

Let those students be especially commended who observe and record the most minute details.

(*c*) EXAMINATIONS.—Try the work constantly. Set test questions on preparatory work; use oral questioning freely during the lesson; have reports made of the lesson and of the practical work; and hold periodical examinations.

Test Questioning.—From five to ten minutes may be set aside at the beginning of every lecture, during which two questions, to be taken alternately round the class, are answered on paper. These can be glanced through by the teacher in a few minutes, whilst the pupils are checking, from their text-books, the answers they have made. Any general correction may be at once made. A careful examination will be made afterwards, and any gross errors mentioned generally, but the names of those whose answers are best may be announced before giving the test questions at the next lecture.

Oral Questioning.—In oral questioning, during and at the close of the lesson, let the pupils, as far as they can, correct erroneous replies.

Reports.—The reports of lessons and of practical work should be sent in for examination within two days; corrected individually by marking imperfections, omissions, and errors; then returned to be amended, where possible, by the pupil himself. These amendments will be scrutinised by the teacher when the book next returns.

No class notice should be taken of any fault that is not tolerably general (unless a rebuke is intended), but the value of each report should be indicated by some sign or letter.

Examinations.—Periodical examinations should be held, and lists published showing the absolute and relative values of the papers.

These should occur every month or six weeks, and opportunity be previously given for revision.

Each examination should cover the whole field of the pupil's work in the subject, special prominence being given to that which is subsequent to the last preceding examination.

Where time will permit, the individual errors and weaknesses should be noticed when the papers are returned.

Absolute values should be assigned to each answer in the paper set, and the aggregate of such values should fix position in the list. To cancel a paper for one or more gross errors in any answer would be to ignore much good work, and to punish neglect of any particular portion of the whole range of work with undue severity.

3. Methods.—General Method.—The method of giving each lesson or lecture must necessarily vary somewhat with the course; but, generally, the organs concerned must first be well known, then the principles involved in the discharge of the function under consideration, and, finally, the application of those principles to the special organs engaged in this work.

It will be understood that no hard and fast line is intended to be drawn here, but that room is left for the exercise of tact and judgment on the teacher's part.

METHOD IN FIRST COURSE.—1. *No Text-Book.*—No text-book whatever should be used by the pupils in this course, but they should gather all their knowledge from freely used diagrams and from models, the teacher rather directing their own efforts to acquire knowledge than imparting it to them, and only helping them when necessary to keep from straying or prevent misunderstanding.

2. *Form-Box.*—The ordinary 'form-box' should be supplemented by others containing models of animals and of the chief internal organs. There should be, what we may call, an inorganic and an organic form-box in every infant school; the latter containing models of typical and familiar animals. For use in the lower classes of every boys' and girls' school should be a second organic form-box, containing models of all the more important internal organs of the human body.

3. *Note-Book.*—On entering the fourth standard each child should be supplied with a note-book, in which brief accounts will be written and sketches made of whatever is studied.

4. *Order of Lesson.*—Commence the lesson by showing the model, picture, or diagram, and obtain from the class whatever can be got by a general survey; then pass it round for closer inspection. Next take up, one by one, the observations made, and arrange them according to their relative importance, doing this by judicious questioning. Sometimes it will be necessary to tell the class what especially to look for; in that case ask for evidence of its presence.

5. *Tests.*—After the first few lessons various models may be given or pictures shown as tests, for each child to identify and describe orally before the class.

6. *Notes of Lesson.*—The following 'notes of a lesson' will probably show more clearly the method intended to be pursued in this preliminary course.

NOTES OF A LESSON ON THE HEART.

Length of lesson, forty minutes; *age of children*, ten years.

MATTER.	METHOD.
I. INTRODUCTION of subject (*a*).	(*a*) Introduce by questioning, to awake interest. Each child's hand just below left breast—pause—ask result. You have kept rabbits, white mice, guinea-pigs, or have had pet dog, kitten or bird in your hand. Did you ever come home and find one dead? How did you know it was dead? Looked at, watched, chirped or called, touched, picked it up and placed hand on breast—not the slightest movement. Something then had stopped. What? Its heart: *Deduction*: 'OUR HEARTS BEAT AS LONG AS WE LIVE.'
II. THE HEART. Its sheath, size, shape and colour (*b*); base, apex; right and left auricles (*d*)—great vessels and positions (*c*), *Pulmonary* (*d*) *Artery* near rim of base, AORTA (*d*) central, two CAVÆ (*d*) into right, and PULMONARY veins into left Auricles.	(*b*) Model of heart—carry round class—get size, shape, colour, sheath and vessels observed—show them base, apex and auricles in connexion with *shape*, and lines of fat in connexion with *colour*—draw attention to attachment of sheath to bases of great vessels.
	(*c*) Make diagram on board to show position of great vessels.
	(*d*) Spelling and meanings of pericardium, auricle, pulmonary, aorta, and cava. Ventricle, bicuspid, tricuspid, and semilunar.
III. POSITION *relative* (*e*) to lungs; between — *absolute* (*f*), base central, apex downwards forwards and to left.	(*e*) Picture of rabbit, showing contents of chest—get relation to lungs and position of base and apex as regards right and left.
	(*f*) Diagram of vertical median section of human chest—observe position as regards top and bottom, back and front of chest. *Deduction*: 'APEX DIRECTLY MAKES BEAT FELT.' Let children pick out great vessels in each diagram, and observe colour of blood in vessels.
IV. INTERIOR — hollow, varying thickness of walls (*g*)—4 chambers, 2 auricles, 2 ventricles (*d*)—openings (*h*) *into* heart no valves; *within*, from auricles to ventricles, BICUSPID (*d*) and TRICUSPID (*i*); *from* heart, semilunar (*d*) valves at Aorta and Pulmonary Artery (*i*).	(*g*) Model should so open vertically as to show chambers and relative thickness of walls—show relation of outward lines of fat to chambers.
	(*h*) Drawings of horizontal sections to show openings and valves.
	(*i*) Diagrams on black board of a Bicuspid or Tricuspid *flap*, and of a Semilunar *pouch*.
V. BILATERAL STRUCTURE OF HEART (*l*).	(*l*) Analogy to nose.
	Previous lessons will render it unnecessary to dwell upon this portion of the lesson.

METHOD IN SECOND COURSE.—1. *Text-Book after Lesson.*—Let the class use a text-book now—and no better book could be desired than Foster's 'Physiology'[1]—but always let the lesson precede its use, or memory will do much that other mental powers should.

2. *Lessons in Pairs.*—In this course the lessons should

[1] *Science Primers. Physiology.* By Dr. M. Foster.

run in pairs, one pair being given per week with an interval of one or two days between. In the first work without, in the second with, text-book. The first lesson should be given as in the first course, except that function should be prominent, and evidence be sought of structural fitness of organ for the work it has to do.

3. *More Details.*—Of course there will be fuller details.

4. *Draw in Note-Book.*—The pupil will now find abundant use for note-book; verbal description and explanation should be encouraged, and sketching made imperative.

5. *Use Natural Objects.*—Natural objects, *carefully prepared beforehand*, may now be placed before the class, and, if properly done, without fear of producing either callous results, or of shocking natural delicacy, and with the certainty of developing observation, since the sense of sight will thereby receive the co-operative aid of the other senses.

6. *Experiments.*—Simple physical, chemical, and mechanical experiments will be performed in nearly every lesson by the teacher, such as the formation of the common gases, the passage of such gases and of solids in solution through membrane, the effects of heat and cold on water, the result of stretching and relaxing elastic bodies, lever action, &c.

7. *Class Use of Text-Book.*—Between the lessons constituting a pair let the child study the subject from his text-book, and in the second lesson let the class read aloud from the book, the teacher commenting and questioning thereon, and verifying the statements. He should also encourage the pupils to ask questions, the class supplying answers when possible. In the latter part of this course the reading in the class might advantageously be dispensed with, and the subject at once discussed.

8. *Rehearsal.*—After this the organ under consideration should be again examined, and the experiments performed, one or more pupils being selected to do this work as an honourable distinction. The second lesson should end with alternate test questions to be answered on paper.

NOTES OF A LESSON ON BREATHING AND THE LUNGS.

Length of lesson, one hour; *age of children*, thirteen years.

MATTER.	METHOD.
I. THE ACT OF BREATHING. Air and lungs concerned (*a*); changes in each, in gases, temperature and moisture *of air* (*b*); in size *of lungs* (*c*); oxygen gives place to carbonic acid (*d*); temperature approximates 100° F. and moisture, saturation—so lungs get rid of carbonic acid, water, and heat, and gain oxygen —expansion of lungs made obvious by rising of chest (*e*).	(*a*) Watch one asleep. How do you know it is *sleep* and not *death*? (*b*) Take long inspiration—observe change in chest—breathe out part of air on cold slate to show moisture and temperature; and remainder through lime-water to show carbonic acid. (*c*) Blow into rabbit's lung or lobe of sheep's.
II. LUNGS AND THORAX. Conical, air-tight chamber; lungs, a cone, but smaller, out of chest; in life vary as chest—lungs always fill chest (*f*); variations result of muscular action of diaphragm (*i*) and intercostal (*i*) muscles of ribs (*g*); *air-vessels*, trachea (*i*), bronchi (*i*), bronchial tubes and sacs let air enter and fill lungs—*blood-vessels*, Pulmonary Artery, air sac capillaries, and Pulmonary veins keep current of blood constant though lungs (*h*).	(*d*) Make oxygen *beforehand*—in class show properties, obtain carbonic acid by burning charcoal in it—show properties of carbonic. *Illustrations* of diffusion of gases—visible action in ginger-beer, lemonade, or cider—change in taste of stale beer or wine even if dry or wet bladder cover it. N.B. Blood is 'A GAS-CHARGED FLUID COVERED BY WET MEMBRANE.' (*e*) Mercury in tube to show pressure of atmosphere. N.B. Caution.—Lungs don't *lift* chest-wall; muscles do, and air pressure fills lungs.
III. FITNESS OF ORGAN FOR ITS WORK. In *position* (*f*) near heart. In *structure* (*h*); hollow, honeycombed, so large surface for exposure of blood—lining, a thin membrane readily permitting diffusion of gases, &c., permanently open pipes communicating with outer air. In highly elastic *property* of tissue (*c*), and so, ready change of capacity.	(*f*) Two drawings of rabbit's thorax, one with uninjured, other with pricked walls—cause of difference in appearance of lungs. (*g*) Experiment with rabbit's lungs in bottle with elastic bottom. (*h*) Diagram of vertical section through trachea and lungs—3 sets of pipes, conveying air, bright and dark blood—their relative positions.
IV. FUNCTION (*k*). By above interchange, to *purify* blood of certain wastes, and to *supply* oxygen and so change venous into arterial blood.	(*i*) Spelling, derivations, and meanings of diaphragm, intercostal, trachea, and bronchus. (*k*) Write on black board.

METHOD IN THIRD COURSE.—1. *Text-Book before Lesson.*—Huxley's 'Elementary Lessons in Physiology,'[1] or some other book of similar character, will suit this course. A certain portion should be set for the pupils to study before the lecture. The thoroughness of this preparatory work having been tested, the lecture itself will proceed much as in the second course, viz.:—

2. *Order of Lesson:*—

1. See objects, experiments, &c.
2. Hear lecture.
3. See objects, &c., again.

3. *Practical Work.*—Then, as soon as convenient, the pupils should have practical work bearing on the subject of the lecture.

4. *Reports and Report-Books.*—Reports of the lecture, with diagrams, and of the practical work, with sketches, should then be sent to the teacher for examination, and as soon as possible returned, marked for correction by the pupil himself. Where great errors are made the teacher should correct *in brief*, leaving the pupil to do it fully.

Rough notes may be taken both of lecture and of practical work, and also of the diagrams employed in the lecture, but the drawings made during the practical work should be final.

The lecture and practical work reports should be in separate books.

The reports should be completed within two days, and the corrections within other two.

5. *Microscope, &c.*—Into our service must now be pressed all the help that science and art can yield. The microscope must be always at hand. Generalisation, inference, and all the higher mental processes should find ample scope.

6. *Preliminary and Explanatory Work.*—In the lectures,

[1] *Lessons in Elementary Physiology.* By T. H. Huxley.

as food-stuffs are considered before alimentation, and levers before motion, so there are certain matters that demand consideration before other functions are attacked; for example—

(*a*) Before Respiration.

a. The diffusion of free gases.
b. Free gas diffuses from a liquid.
c. Free gas diffuses through either a dry or wet porous membrane.
d. Water dissolves carbonic acid gas more readily than it does oxygen.
e. Carbonate of lime is formed by the passage of carbonic acid gas through lime-water.
f. The gases of the atmosphere are *mechanically* mixed.
g. Hæmoglobin of red blood corpuscles has some chemical affinity for oxygen.

(*b*) Before Hearing.

a. Nature of sound waves.
b. Relation of sound to a stretched membrane.
c. Vibration of particles individually and *en masse.*
d. Sympathy of a tuning-fork, &c., to a particular note.

(*c*) Before Seeing.

a. Nature of light.
b. Influence on light of media varying in density.
c. Influence of convex, concave, and biconvex lenses on light.
d. Relation between distance of focus and that of object.
e. Relation between nearness of focus and degree of convexity.
f. Inversion and reversal of images.

7. *Modus Operandi.*—After the body of the lecture has been given, the means by which the principles concerned are so employed by the organs as to result in the proper discharge of the function, should be briefly summarised.

Take as example, HEARING, and show the steps by which the physical agent, *Air waves*, results in the mental phenomenon, *Sound*. Thus :—

a. AIR WAVES passing up meatus impinge on tympanic membrane.

b. Vibration of tympanic membrane.

c. Oscillation of auditory ossicles, and also production of waves in air of tympanum.

d. Vibration of membranes of fenestræ ovalis and rotunda.

e. Vibration of perilymph and contents, viz., membranous labyrinth and scala media.

f. Vibration of endolymph and contents, viz., hairs, otoconia and fibres of Corti.

g. Stimulation of fibres of auditory nerve.

h. Transmission of impulse to brain.

i. Consciousness of SOUND in the mind.

8. *Practical Work*.—Practical work should follow as close on the lecture as possible. For instance, after a lecture on the eye, that organ from an ox or other animal should be critically examined in some such way as the following.

DISSECTION OF EYE OF OX OR SHEEP.

A dish with water, a paraffin tablet, scalpel, pair or scissors, forceps, needle and pins will be needed.

Pick off the fat and reveal the muscles and optic nerve ; observe point of entrance of optic nerve to ball ; remove the muscles and reveal the sclerotic ; observe line of junction with cornea ; pin the eye on the tablet, with cornea upwards ; make incision on cornea, aqueous humour spirts out ; with scissors, cut away cornea and examine it ; observe, it becomes opaque when stretched ; note iris resting on the lens ; gently squeeze the eye-ball, and the lens (perhaps in its capsule) rises through the iris ; remove lens-capsule and examine ; insert needle in equator of crystalline lens ; note

evidence of its high density, and also the different degrees of convexity before and behind; preserve it for sections; remove iris and examine; observe blood-vessels, &c., through vitreous humour; remove vitreous humour and with it the retina by parting the ciliary processes and cutting through the blind spot; examine retina and preserve for sections; with forceps raise choroid coat; examine its pigment cells; and, lastly, the strong sclerotic capsule. The iris, ciliary muscles, retina, lens, and pigment cells should be examined under the microscope.

4. Apparatus.—Both in conducting lessons and practical work certain special apparatus is necessary for teacher and pupil.

For Class Purposes.—A box of coloured chalks for black-board use; a set of physiological charts; numerous small separate diagrams; models, especially of ear, eye, and skull with brain; a good microscope, with inch and quarter-inch lenses, and materials for mounting, viz., glass slides and covering glasses, wire clips and Canada balsam, soluble Prussian blue and carmine; a small spirit lamp; a syringe and pipettes; several different-sized test tubes; bottles of distilled water, salt solution, limewater, glycerine, and methylated spirit; acetic, nitric, and chromic acids, and a few other chemicals, as bicarbonate of soda, sulphate of soda, ferrocyanide of potassium, and nitrates of silver and barium.

For Individual Use.—A magnifying glass, a scalpel, a pair of scissors, several sizes of needles and pins (the former square in section, the latter with large black heads), a box of crayons, some stout cardboard, cork, and a paraffin tablet.

Spottiswoode & Co., Printers, New-street Square, London.

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